# JBaby

A dissertation submitted in partial fulfilment of
the requirements for the degree of

BACHELOR OF ENGINEERING in Computer Science

in

The Queen's University of Belfast

by

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2 May 2006

## Declaration of Originality

I declare that this report is my original work except where stated.

Signed _____ Date _____

# ACKNOWLEDGEMENTS

I would like to thank the various people who helped test the system. Without their participation the system would not be as robust and stable. I would especially like to thank, Fiona Sullivan, Jamie Addis, John Eakin, Philip Johnston and David Hewitt for the time and effort that they dedicated to thoroughly testing the system.

I would also like to thank Professor D. Crookes, my project supervisor, for dedicating his time for his assistance and advice in the design, implementation and documentation of my project.

# ABSTRACT

The development of motor skills are extremely important in a child's development and can help children perform better in other, more academic and physical ways. However the teaching of these invaluable skills is often forgotten about or ignored.

The aim of this researched based project was to build a system to address this issue using cheap, everyday technology. The final system works extremely well and successfully completes its purpose, which was to analysis if a child is clapping in time with an audio sequence. With further research and development, systems like this one, could be successfully used to help children improve motor skills such as rhythmic clapping.

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# 1. INTRODUCTION

## 1.1 Overview

The aim of this project is to build a computerised system which uses vision to capture a child's movements and has a musical/audio output which will help stimulate movement. This system will help children develop co-ordinated movements in their hands and arms and accomplish simple tasks such as rhythmic clapping.

## 1.2 Background information

It has been medically proved that children's motion control and co-ordination is extremely important in a child's development and can encourage them to perform better in other, more academic and physical ways. Therefore stimulating children's motion control and co-ordination is extremely important and an area which can not be neglected.

# 2.0 REQUIREMENTS ANALYSIS

## 2.1 How the problem is currently solved

The problem starting point, assumes that the child can already clap and the objective is to encourage rhythmic clapping. This is currently solved by a guardian teaching children rhythm using a variety of techniques. One such technique is to get the child to clap in time with music. The guardian will then note and reward how well the child is clapping in time with the music. Another technique is to encourage the child to repeat rhythms which have been clapped out by the guardian.

## 2.2 The shortcomings of the current solution

One-to-one attention isn't cost effective for child minders. Parents don't always have enough time to spend teaching children these invaluable skills. Therefore the teaching of skills such as rhythmic clapping can get neglected.

Another problems is that it is difficult to quantify how well the child is keeping in time with the music.

## 2.3 Proposed New System

The proposed system is essentially an experiment to investigate the technology aspects, which if successful could open up the possibility of developing a full system for real life use.

The system will use vision to capture a child's movements and have a musical/audio output to help stimulate co-ordinated, rhythmic clapping from the child. Visual feedback will be given to show the child how well they are clapping in time with the music.

To simplify the task of determining the movements we envision that the child will wear coloured gloves.

There will be three users of the system; the child, operator in research mode and operator. The users and how they will interact with the system are shown in the diagram below.

### 2.3.1 Diagram of the system

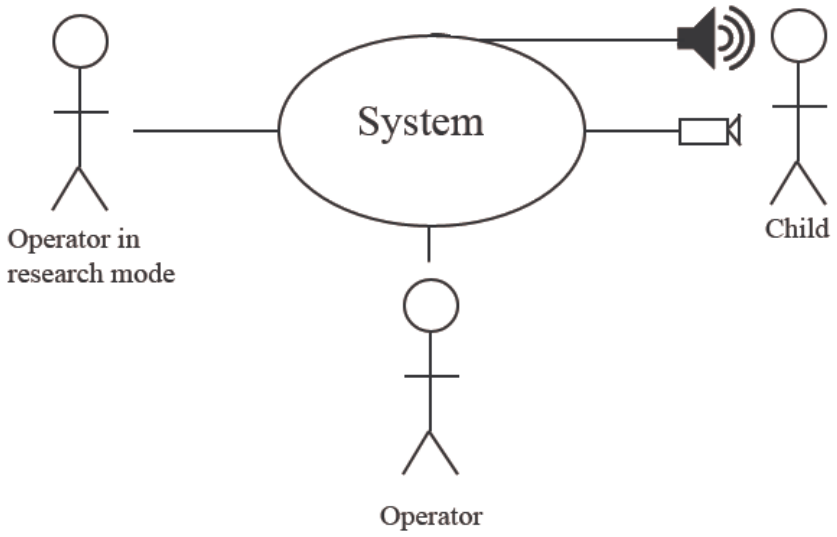



Figure 1: Top level diagrammatic view of the system.

## 2.4 Functional Requirements

Requirements marked with a star (*) are additional features which are not part of the core requirements but are extra, non essential requirements which add extra functionality to the system.

### 2.4.1 Core Functional Requirements

There are a number of core functional requirements which are carried out by the system but don't require any input from a user. These can be grouped together under two categories, video and image processing requirements and audio requirements.

#### 2.4.1.1 Video and Image Processing Requirements

1. Capture of a video stream from a web camera.
2. Opening a video sequence from a file.
3. Segmentation: Separation of the hands from the background.
4. Display of original video sequence.
5. Display of segmented video sequence.
6. Motion detection: Record motion properties (the direction, distance and speed each hand has moved between every frame)
7. Motion interpretation: The system will classify the current motion into one of five categories;
    a) Hands moving apart
    b) Hands moving together
    c) Hands still
    d) Hands touching
    e) Other (for any other scenarios which don't fit into any of the above categories)

#### 2.4.1.2 Core Audio Requirements

1. A music clip can be played continuously.
2. The tempo of the music clip can be detected.
3. The tempo of the music clip is software controllable.

### 2.4.2 Functional Requirements for the Child

1. The child interacts with the system by attempting to clap in time with the music.
2. Visual feedback will be provided to the child, so they know how well they are clapping in time with the music.

### 2.4.3 Functional Requirements for the Operator

The functional requirements for the operator can be grouped together under two sections, video and audio.

#### 2.4.3.1 Video

1. Monitor the child's movements.
2. Monitor the systems interpretation of the child's movements.
3. Choose the colour to track.
4. Control the colour thresholds for more robust segmentation in varying lighting conditions.

#### 2.4.3.2 Audio

1. Control the speed of the music clip *
2. Select the music clip to be played *
3. Mute music clip

### 2.4.4 Functional Requirements for the Operator in research mode

1. Choose to run the program either live or from video file for testing purposes.
2. Facilities for optimising and calibrating the separation of the hands from the background;
    i. Provide the option of average thresholding.
    ii. Provide the option of background thresholding.
3. Experiment with applying various appropriate pre-processing imaging operations to investigate the trade-off between quality of segmentation and speed of operation. In particular, the operator should be able to experiment with and without;
    i. Open (to remove speckle and noise)
    ii. Close (to close small gaps e.g. avoid a hand being split in two)
4. Single step through a video sequence for analysis purposes *
5. Analysis Functions. The system will display the results of the motion interpretation (2.4.1.1(6)) and also other details such as the location of each hand, and the distance, direction and speed each hand has moved between the previous frame and the current.

### 2.4.5 Non Functional Requirements

1. The system must have an intuitive and easy to use front end interface.
2. The live video frames must be processed in real time
3. A low cost web cam must be used.

## 2.5 Familiarisation

Familiarisation with three key areas must be undertaken before any development can commence. These areas are outlined below.

### 2.5.1 Video input and output

There are four main stages involved this area;

1. Capture of a video sequence from a web cam.
2. Reading of a video sequence from file.
3. Accessing the video sequence frame by frame.
4. The display a video sequence

Java Media Framework (JMF) will be used to implement the above tasks.

### 2.5.2 Digital Image Processing

Digital image processing is an area which deals with analyzing and manipulating images. An extensive knowledge of this are is needed in order to successfully extract useful and meaningful information from the video sequence.

The separation of the hands from the background is the most important image processing task.

Java Advanced Imaging (JAI) will be used to implement the image processing algorithms.

### 2.5.3 Sound processing

A knowledge of sound processing is needed, first of all to play a music clip (continuously) that the child can clap along with and secondly to get the tempo of the music to check if the child is actually clapping in time with the music.
Java Sound will be used to implement the above tasks.

# 3. FUNCTIONAL SPECIFICATION

This section further defines the functional requirements set out in the Requirements Analysis Section (Section 2)

## 3.1 Data Model

A data model (figure 2 on the next page) is needed to introduce the basic functions of the system and to show how they interact. It also introduces the variables which are used later in the functional specification section. The display areas are also included in the data model.

Note: Although in practice the system will process one frame at time, we conceptually regard and process all frames and intermediate frames sequences as a block. This notion will be used throughout the functional specification section.

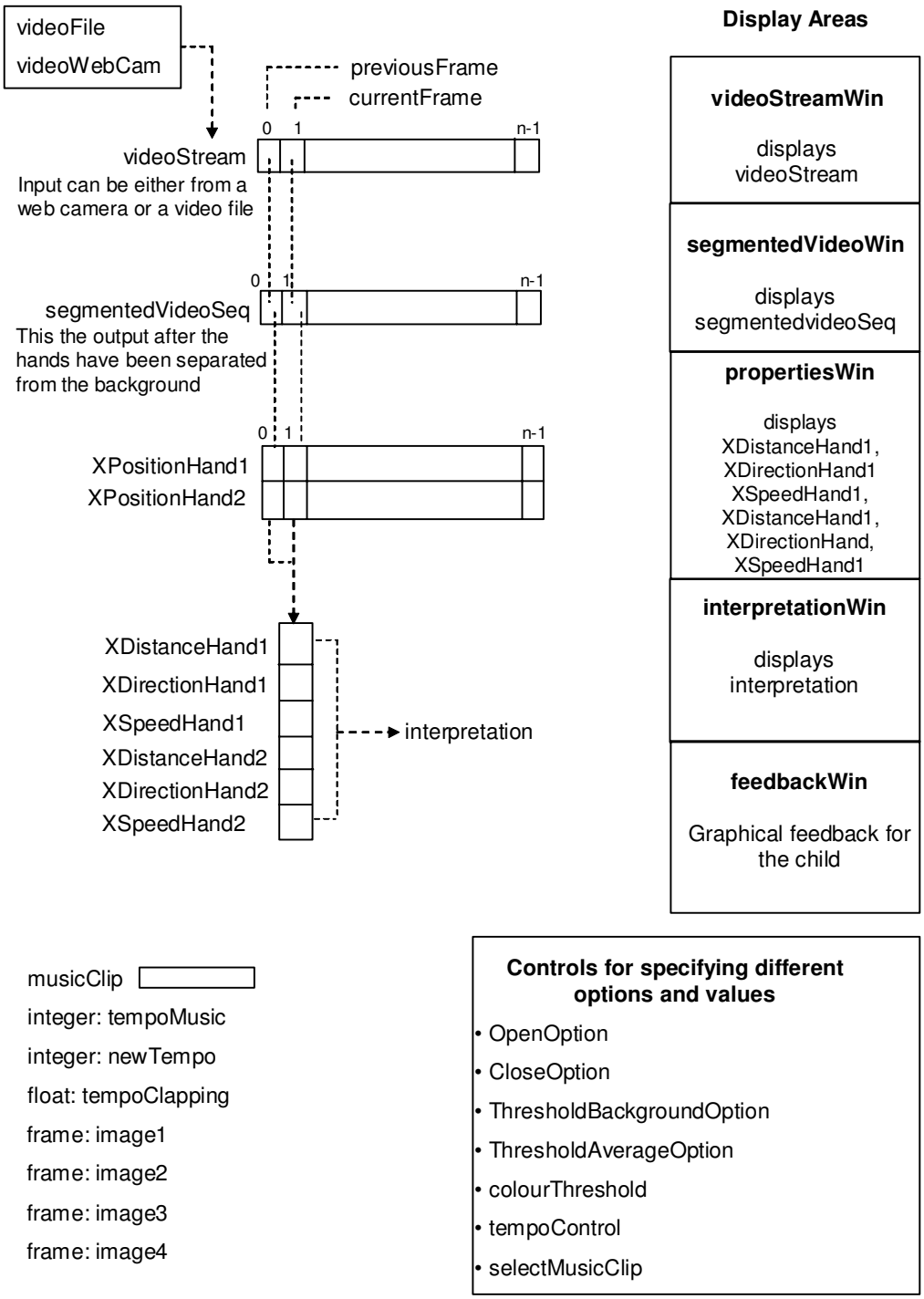



Figure 2: A Data model of the proposed system

## 3.2 Functional Specification Definition

All of the requirements specified in the requirements section (section 2) are set out under the following headings;

- Core system functions
- Functions for the operator
- Functions for the operator in research mode

Each function is described by a table with the following fields;

- Inputs: Data which is passed into the function
- Behaviour: A definition, in terms of the data model of what the function does
- Pre-protocols: External actions or events that need to occur before the function can begin
- Post-protocols: The state of the system after the function has completed
- Error conditions: Any error conditions that should be checked for

### 3.2.1 Core System functions

These are core system functions which are not specifically carried bout by any user but by the system itself. These functions can be further divided into two sections; core video and image processing functions and core audio functions.

#### 3.2.1.1 Core Video and Image Processing Functions

Requirement 2.4.1.1(1)

| | |
|---|---|
| **Name** | Capture the video stream from a web camera |
| **Inputs** | videoWebCam |
| **Behaviour** | Change input to input from a web camera<br><br>videoStream = videoWebCam |
| **Pre-conditions** | Web camera is plugged in and is not being used by another application |

Requirement 2.4.1.1(2)

| | |
|---|---|
| **Name** | Read video sequence from file |
| **Inputs** | videofile |
| **Behaviour** | Change input to input from a file<br><br>videoStream = videoFile |
| **Pre conditions** | File exists |
| **Error conditions** | File contains a valid video sequence |

Requirement 2.4.1.1(3)

| **Name** | Segmentation |
|---|---|
| **Inputs** | videoStream |
| **Behaviour** | This function accepts as an input, the original video sequence and returns a segmented version of the video sequence and a list of non-connected objects, ranked by size.<br><br>The first stage of the function is thresholdBackground. This is a function which subtracts an image of the background from every frame.<br><br>The next stage is thresholdAverage. This segments the frame using brightness.<br><br>colourSegmentation is the final segmentation stage, it is not optional and segments the frame by colour.<br><br>Open and close are optional post processing functions which clean up the image.<br><br>for all i<br>if thresholdBackOption is selected<br>thresholdBackgroundVideo =<br>thresholdBackground(segmentedVideoSeq)<br>else<br>thresholdBackgroundVideo = segmentedVideoSeq<br>if thresholdAverageOption is selected<br>thresholdAverageVideo =<br>thresholdAverage (thresholdBackgroundVideo)<br>else<br>thresholdAverageVideo = thresholdBackgroundVideo<br>if colourSelected<br>segmentedVideoSeq =<br>colourSegmentation(thresholdBackgroundVideo)<br>if openOption is seletected<br>open()<br>if closeOption is selected<br>close() |
| **Pre conditions** | User has selected the colour of the gloves to track |

Requirement 2.4.1.1(4)

| **Name** | Display of original video sequence |
|---|---|
| **Inputs** | videoStream |
| **Behaviour** | Display takes videoStream as an input and returns a window displaying this video sequence.<br><br>videoStreamWin = display(videoStream) |

Requirement 2.4.1.1(5)

| **Name** | Display of segmented video sequence |
|---|---|
| **Inputs** | segmentedVideoSeq |
| **Behaviour** | Display takes segmentedVideoSeq as an input and returns a window displaying this video sequence.<br><br>segmentedVideoWin = display(segmentedVideoSeq) |

Requirement 2.4.1.1(6)

| **Name** | Record motion properties for each hand |
|---|---|
| **Inputs** | SegmentedVideoSeq |
| **Behaviour** | This function records the following motion properties<br>• distance<br>• direction<br>• speed<br><br>These values are worked out my comparing the hand position in the current frame (frame i) with the position of the same hand in the previous frame (i-1)<br><br>Note: This can't start until i>1 (to stop a frame which doesn't exist being accessed).<br><br>for all i<br>XPositionHand1[i] = findXPositionHand1()<br><br>XPositionHand2 [i] = findXPositionHand2()<br><br>XDistanceHand1 =<br>disanceBetween( XPositionHand1[i] , XpositionHand1[i-1] )<br><br>XDistanceHand2 =<br>disanceBetween( XPositionHand2[i] , XpositionHand2[i-1] )<br><br>XDirectionHand1 =<br>direction( XPositionHand1[i] , XpositionHand1[i-1] )<br><br>XDirectionHand2 =<br>direction( XPositionHand2[i] , XpositionHand2[i-1] )<br><br>XSpeedHand1 = speed(XDistanceHand1)<br><br>XSpeedHand2 = (XDistanceHand2) |
| **Error conditions** | If the segmentation gives less than two objects. The motion properties are only recorded for that one object (this occurs when the hands are touching) |

Requirement 2.4.1.1(7)

| **Name** | Motion interpretation |
|---|---|
| **Inputs** | XDirectionHand1, XDirectionHand2 |
| **Behaviour** | Accepts as inputs the direction hand 1 is moving and the direction hand 2 is moving and returns a classification of the current motion; hands moving apart, hands moving together, hands still and apart, hands touching or other for any classification which doesn't fit into the first four categories.<br><br>interpretation = interpret(XDirectionHand1, XDiectionHand2) |

### 3.2.1.2 Core Audio Functions

Requirement 2.4.1.2(1)

| **Name** | Start playing a music clip continuously |
|---|---|
| **Inputs** | newMusicClip |
| **Behaviour** | If there is a music clip being played, it will end and the new music clip will begin to play. Otherwise the new music clip will begin to play<br><br>musicClip = newMusicClip |
| **Post conditions** | Continuously playing music clip |

Requirement 2.4.1.2(2)

| **Name** | Detect the tempo of the music clip |
|---|---|
| **Inputs** | musicClip |
| **Behaviour** | Accepts a music clip as an input and returns the tempo of the music clip.<br><br>tempoMusic = findTempo(musicClip) |

Requirement 2.4.1.2(3)

| **Name** | Set the tempo of the music clip |
|---|---|
| **Inputs** | tempoMusic, musicClip |
| **Behaviour** | Acepts as an input a music clip and an integer value. It changes the tempo of the music to the integer value.<br><br>changeTempo(musicClip, tempoMusic) |
| **Post conditions** | musicClip with its tempo changed to the value of tempoMusic |

## 3.3 Functional Specification for the Child

Requirement 2.4.3.2(1)

| | |
|---|---|
| **Name** | The child interacts with the system by attempting to clap in time with the music. |
| **Inputs** | Child clapping along with the music |
| **Behaviour** | The system records the tempo of the child's claps.<br><br>tempoClapping = tempo of the child's clap |

Requirement 2.4.3.2(2)

| | |
|---|---|
| **Name** | Visual feedback will be provided to the child, so they know how well they are clapping in time with the music. |
| **Inputs** | tempoClapping, tempoMusic |
| **Behaviour** | Interpret the current motion and then display "encouragement" for the child. There are five different levels of encouragement (i.e. very good, good, ok, bad, very bad).<br><br>It is sufficient to determine the absolute value of the quality of clapping, rather than having a dynamic improvement function which would smile if the child started to improve, even though he or she is still not clapping in time with the music.<br><br>feedbackWin = display(tempoClapping, tempoMusic) |

## 3.4 Functional Specification for the Operator

The functions for the operator can be divided into two sections; video and image processing functions for the operator and audio functions for the operator.

### 3.4.1 Video and Image Processing Functions for the Operator

Requirement 2.4.3.1(1): Monitor the child's movements
The operator can monitor the child's movements by watching the videoStreamWin display area. This displays the original video sequence, and so by watching this display area the operator can monitor the child's movements.

Requirement 2.4.3.1(2) Monitor the system's interpretation of the child's movements.
The operator can monitor the system's interpretation of the child's movements by watching the interpretationWin classifies the current motion into one of following five scenarios;

- Hands moving apart
- Hands moving together
- Hands still
- Hands touching
- Other (for anything scenario which doesn't fit into the above four categories)

Requirement 2.4.3.1(3)

| | |
|---|---|
| **Name** | Control the colour thresholds for more robust segmentation in varying lighting conditions. |
| **Inputs** | colourThreshold, videoStream |
| **Behaviour** | A value (chosen by the user) is passed into the segmentation method. By changing this value, the user can optimise the quality of the segmentation<br><br>for all i<br>sementedVidSeq =<br>segmentation(videoStream[i], colourThreshold) |
| **Pre conditions** | Segmentation has actually started (i.e. the user has picked a colour to track) |

### 3.4.2 Audio Functions for the Operator

Requirement 2.4.3.2(1)

| | |
|---|---|
| **Name** | Control the tempo of the music |
| **Inputs** | controlTempo, newTempo |
| **Behaviour** | The user controls the tempo of the music using the control option controlTempo. newTempo is set to the value of controlTempo. The system then changes the tempo of the music to this new value ( see 3.1.2.2(3) )<br><br>newTempo = controlTempo |
| **Pre conditions** | A music Clip must be playing |

Requirement 2.4.3.2(2)

| | |
|---|---|
| **Name** | Select the music clip to be played |
| **Inputs** | musicClip |
| **Behaviour** | Allows the user to choose a musicClip. The current music clip is change to the clip which the user has selected using the control option selectMusicClip.<br><br>musicClip = selectMusicClip |
| **Error conditions** | The chosen file must be a valid music clip |

Requirement 2.4.3.2(3)

| | |
|---|---|
| **Name** | Mute music clip |
| **Inputs** | musicClip |
| **Behaviour** | Accepts as an input a music clip and returns the musicClip with the volume muted.<br><br>musicClip = mute(musicClip) |
| **Pre conditions** | A music clip must be playing |
| **Post conditions** | musicClip |

## 3.5 Functional Specification for the Operator in research mode

Requirement 2.4.4(1)

| | |
|---|---|
| **Name** | Choose to run the program either live or from a video file |
| **Inputs** | videoFile<br>videoWebCam |
| **Behaviour** | The function changes the video sequence to a video source from the newly selected input mode. If the user selects file, the user must be prompted to enter or select what file he or she wants to play.<br><br>videoSequence = videoFile or videoWebCam |
| **Post conditions** | videoSequence |

Requirement 2.4.4(2a)

| | |
|---|---|
| **Name** | Control threshold average |
| **Inputs** | thresholdAverageOption |
| **Behaviour** | The user can turn the threshold average option off and on from the control area (by changing the control variable thresholdAverageOption).<br><br>thresholdAverageOption = on<br>thresholdAverageOption = off |
| **Pre conditions** | Segmentation must be running (i.e. the user must have clicked on an object to track) |
| **Post conditions** | Segmentation occurs using thresholdAverage if the option is turned on, otherwise threholdAverage isn't used. |

Requirement 2.4.4(2b)

| **Name** | Control threshold backround |
|---|---|
| **Inputs** | image2 |
| **Behaviour** | The user can turn the threshold background option off and on from the control area (by changing the control variable thresholdBackgroundOption).<br><br>thresholdBackgroundOption = on<br>thresholdBackgroundOption = off |
| **Pre conditions** | Segmentation must be running (i.e. the user must have clicked on an object to track) |
| **Post conditions** | Segmentation occurs using thresholdBackground if the option is turned on, otherwise threholdBackground isn't used. |

Requirement 2.4.4(3a)

| **Name** | Turn open on |
|---|---|
| **Inputs** | openOption |
| **Behaviour** | The user can turn the open option off and on from the control area (by changing the control variable openOption).<br><br>openOption = on<br>openOption = off |
| **Pre conditions** | Segmentation must be running (i.e. the user must have clicked on an object to track) |
| **Post conditions** | Segmentation occurs using thresholdBackground if the option is turned on, otherwise threholdBackground isn't used. |

Requirement 2.4.4(3b)

| **Name** | Turn close on |
|---|---|
| **Inputs** | closeOption |
| **Behaviour** | The user can turn the close option off and on from the control area (by changing the control variable closeOption).<br><br>closeOption = on<br>closeOption = off |
| **Pre conditions** | Segmentation must be running (i.e. the user must have clicked on an object to track) |
| **Post conditions** | Segmentation occurs using thresholdBackground if the option is turned on, otherwise threholdBackground isn't used. |

Requirement 2.4.4(4)

| **Name** | Single step through video sequence for analysis purposes |
|---|---|
| **Inputs** | videoSequence |
| **Behaviour** | currentFrame = videoSequence[head]<br>head = head + 1 |
| **Error conditions** | Input must be from a video file and not from a web camera |

Requirement 2.4.4(5)

The information returned from the motion properties function (2.4.1.1(6)) and the motion interpretation (2.4.1.1(7)) function will be displayed in the propertiesWin and interpretationWin respectively.

# 4. DESIGN

There are various design methodologies which could have been used to design this system e.g. the waterfall model, evolutionary prototyping model and the incremental model. The evolutionary prototyping model has been used in this system. This approach was chosen because prototyping is ideal when the requirements are not fully known at the beginning. This approach allows a working prototype to be up and running extremely quickly. Using this prototype, the requirements can be further refined.

This design section is split up into two sections; graphical user interface design and software design.

## 4.1 Graphical User Interface Design

Since this system is intended as an experimental research project, it was decided to have a single operator interface (i.e. one interface for the operator and the operator in research mode). The child has a user interface of his or her own.

### 4.1.1 Graphical user interface for operator including research mode

From the Functional Specification (Section 3) it was decided that the user interface (for the operator and operator in research mode) should contain 5 display areas;

- The input video sequence
- Segmented video sequence
- Motion properties (e.g. distance, direction and speed for each hand)
- System's interpretation of the child's movements including the feedback given to the child (e.g. hands moving together, hands moving apart, hands touching)
- A control panel for optimising and controlling the image processing operations and to control the tempo of the audio sequence.

For good layout purposes, some of the areas have been compacted and are not rectangular. An annotated screen shot of the actual user interface is shown in figure 3 below.

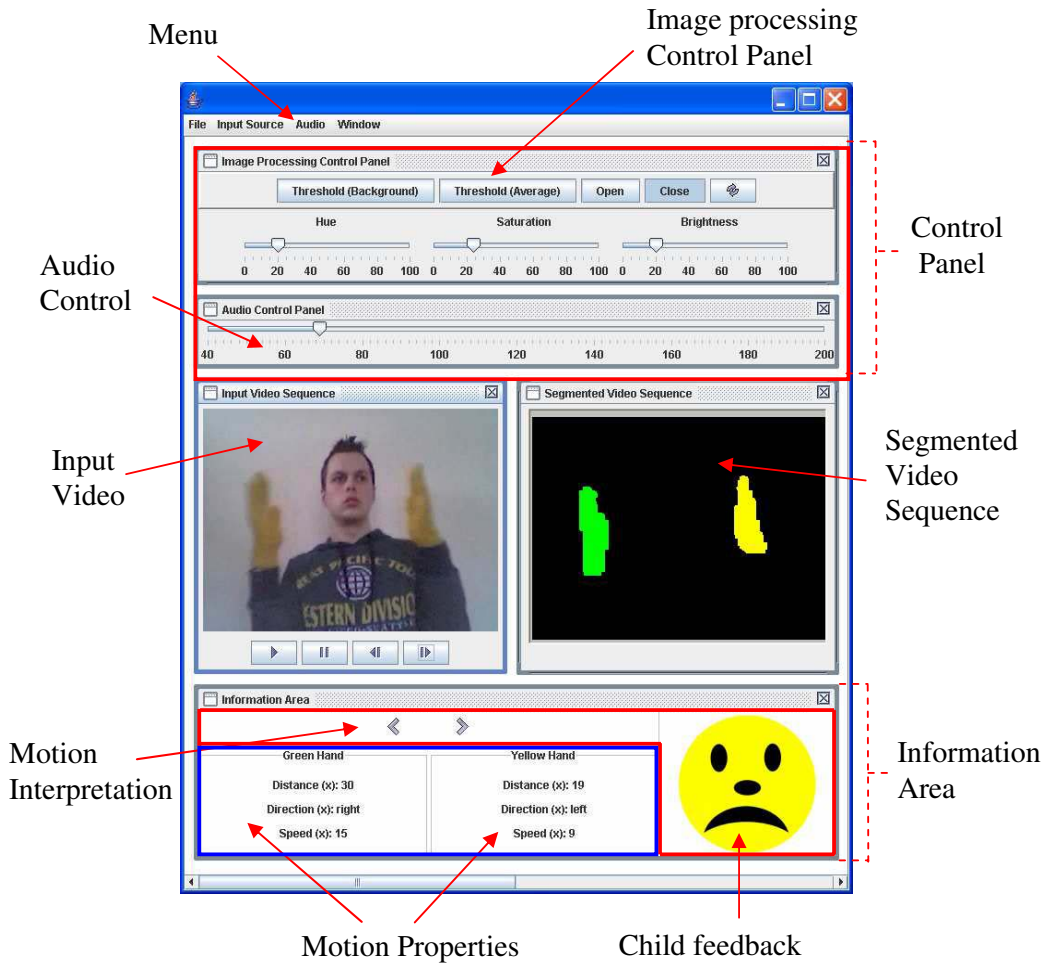



Figure 3: User Interface for the operator and operator in research mode

The user interface consists of a desktop pane, with smaller internal windows sitting on top of this pane. The decision was taken to use internal windows, so that any of the displays areas (windows) can easily be disposed of. A user interface like this is needed since two different operators share the same user interface (operator and operator in research mode). The user can position and remove any of the display areas and essentially create a user interface to suit himself (e.g. the operator might want to get ride of the image processing control panel, since he is not concerned with image processing operations)

#### 4.1.1.2 Structure of the menu items

Table 1 below, shows the structure of the menu, along with a brief description each menu item.

| | |
|---|---|
| **File** | |
| Open | Opens a video file |
| Quit | Exit the system |
| **Input Source** | |
| Video File | Selects input from a video file |
| Web Camera | Selects input from a web camera |
| **Audio** | |
| Select Audio Sequence | |
| List of Songs | User selects audio clip from the list of songs |
| Audio Sequence | Mute/unmute audio sequence |
| Clapping Sound Effect | Mute/unmute clapping sound effect |
| **Window** | |
| Image Processing Control Panel | Display/remove image processing control panel |
| Audio Control Panel | Display/remove audio control panel |
| Input Video Sequence | Display/remove input video sequence |
| Segmented Video Sequence | Display/remove segmented video sequence |
| Information Area | Display/remove information area |
| Child feedback | Display/remove the child feedback area |

Table 1: Table showing the structure of the menu system

A more detailed description of some of the menu items is required. This is given on the following page, along with pseudo code for the event handlers which will be carried out when the user clicks on the menu item.

#### 4.1.1.3 Description of the non-obvious menu items

**1. Open**

Open is a function which allows the operator to choose the video file which is to be played. When the operator clicks on open a file chooser dialog box appears, from which the user can choose a video file. The pseudo code for the event handler is outlined below.

*Display file chooser*
*OK: video Sequence = video file which the user chooses*
*Cancel: video Sequence = previous video Sequence*

**2. Video File**

The menu item video file, changes the input source from a web camera to a video file. When this menu item is clicked on, an open dialog box will appear allowing the user to select a video file. The pseudo code for this event handler will not be shown, since it is essentially the same as the event handler for the open menu item which was described above.

**3. Window**

The audio control panel will be used an example, however the behaviour is the same for each of the windows. If the audio control panel is currently displayed on the screen and the user clicks on the menu item audio control panel, the window will be disposed of. The next time the user clicks on this menu item, the audio control panel will be redrawn in the user interface. Each of these windows can also, be disposed of by clicking on the 'x' which is located on the top right hand side of all of the windows. If the window is disposed of in this manner, it can be brought back by clicking on the appropriate menu item.

The event handler for each of the windows is essentially the same therefore a generic variable ‘window’ has been used in the pseudo code below.

*If window is currently displayed on the screen*
    *Dispose of window*
*Else*
    *Display window*

**4. Select Audio Sequence**

When this menu item is clicked on, a sub menu will appear listing a number of audio sequences. The selected audio sequence will start to play

We now present the GUI design, showing how the requirements are to be realised through the GUI;

#### 4.1.1.4 Image Processing Control Panel

This area contains the following controls to optimise and fine tune the segmentation process;

**Open**

Turns the morphology operation ‘open’ on or off (requirement 2.4.4(3a))

**Close**

Turns the morphology operation ‘close’ on or off (requirement 2.4.4(3b))

**Threshold (Background)**

Turns the thresholding operation ‘thresholdBackground’ on or off (requirement 2.4.4(2a))

**Threshold (Average)**

Turns the thresholding operation ‘thresholdAverage’ on or off (requirement2.4.4(2b))

**Hue, Saturation and Brightness**

These are three sliders which are used to optimise and control the colour segmentation.

**Refresh**

Use to refresh the segmented video sequence after any of the above operations have been applied (used when in single stepping through video sequence mode)

#### 4.1.1.5 Audio Control Panel

Contains a slider to change the tempo of the music (requirement 2.4.2.1(1))

#### Input Video Sequence

The input video sequence can be from a video file or from a web camera. If the input is from a video file the operator has additional controls over the video sequence. These controls are to step through the video sequence one frame at a time.

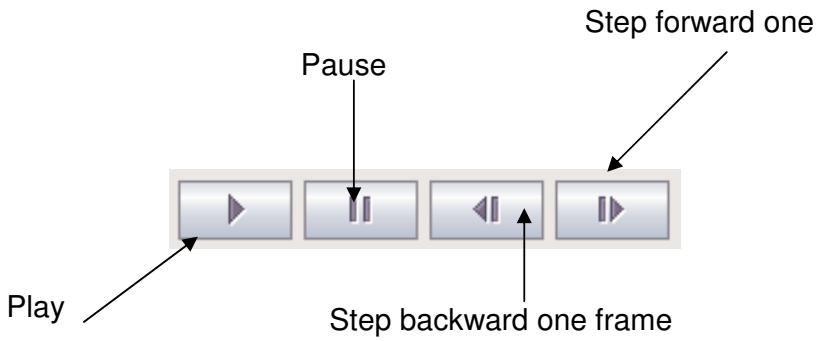



Figure 4: The video controls

#### 4.1.1.6 Segmented Video Sequence

Displays the segmented video sequence, coloured coded (green for the hand on the left, yellow for the hand on the right and red if the hands are touching) as shown figure 5 below

Figure 5: A diagram illustrating the coloured coded segmented video sequence

#### 4.1.1.7 Information Area

This window contains three information areas which are outlined below.

**1. Motion Properties**

This area displays the motion properties as text from the current frame i.e. for each hand, in the x direction, the distance, speed and direction moved since the last frame.

**2. System's Interpretation of the Child's Movements.**

A different symbol is displayed depending on how the system classifies the current movements of the hands. Below is a table showing all the symbols which can be displayed along with a description of what each symbol means.

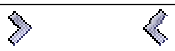
| Symbol | Description |
|---|---|
| | Hands moving apart |
|  | Hands moving together |
| | Hands still but not touching |
| | Hands touching |
| | Other. No symbol is displayed if the current scene can't be classified into one of four above scenarios. |

Table 2: Table showing the symbols representing the system's interpretation of the child's movements

**3. Child feedback**

This display area displays the same visual feedback which is given to the child (see4.1.2). This is to ensure that the operator knows who well the child is performing

### 4.1.2 User interface the child

Apart from the camera for input, the user interface for the child is simply a face. This face is displayed in a separate window. This is so that the system can be run on two monitors. The user interface for the operator would be displayed on one monitor and the child's user interface is displayed on the other monitor. The user interface for the child can be maximised so that the child sees nothing else. Figure 6 below shows the user interface for the child.

Figure 6: Screen shot of the user interface for the child

There are five different faces which are displayed depending on how well the child is clapping in time with the music. A smiley face is displayed when the child is keeping in time with the music and a frown is displayed when the child is completely out of time with the music. The five different faces are shown in figure 7 below.

Figure 7: The feedback which is given to the child

## 4.3 Software Design

This section details the design of the main algorithms in the system. It is structured using a top down analysis type approach, gradually breaking the system down from very general components to into more specific objects.

The first logic breakdown of the system is to identify the user interactions and the external components (e.g. a web camera) which interact with the system.

### 4.3.1 Top level design

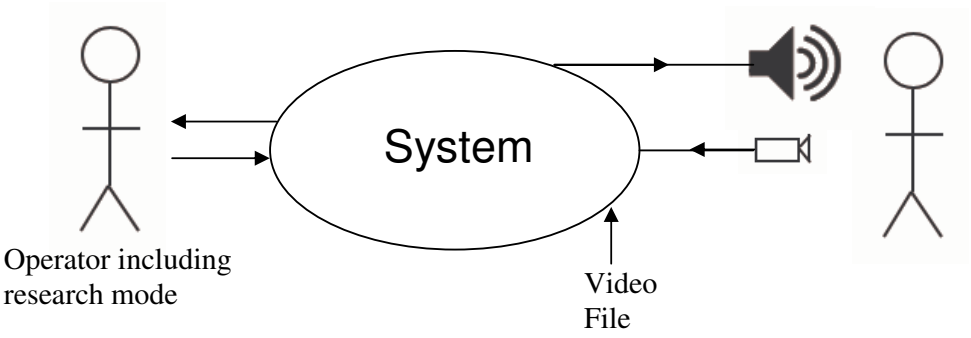



Figure 8: Top level diagram of the system

We now further decompose the system component to give us the first level of decomposition.

### 4.3.2 First Level Decomposition

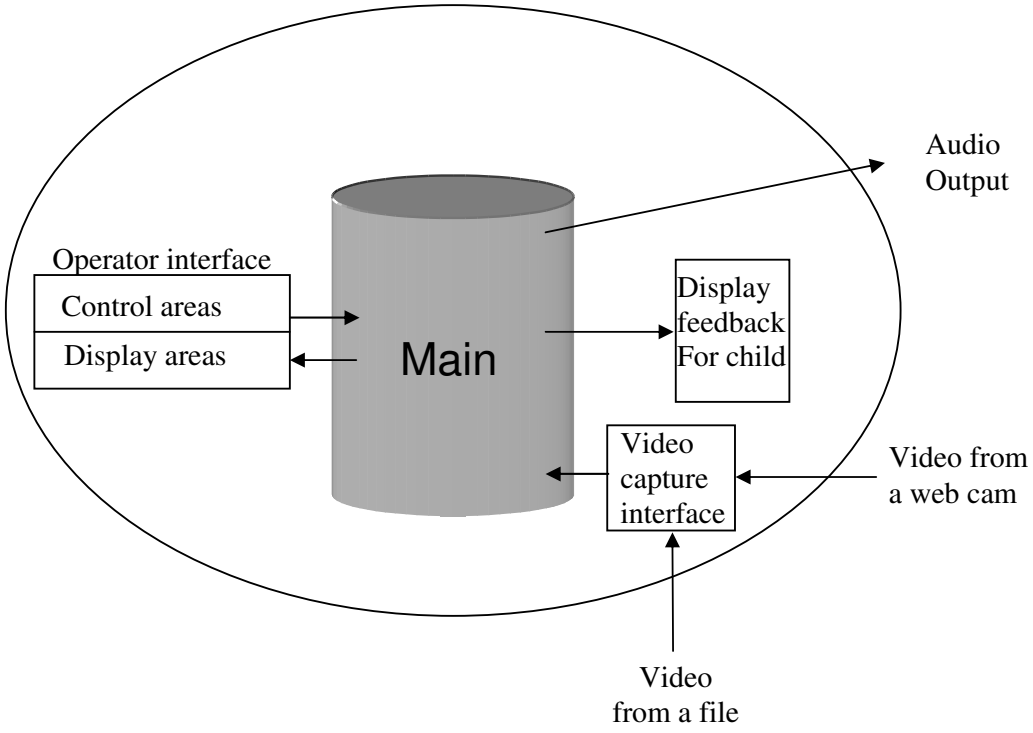



Figure 9: First level decomposition of the system

Refining the central ‘main’ processing object gives us the second level of decomposition.

### 4.3.3 Second Level Decomposition

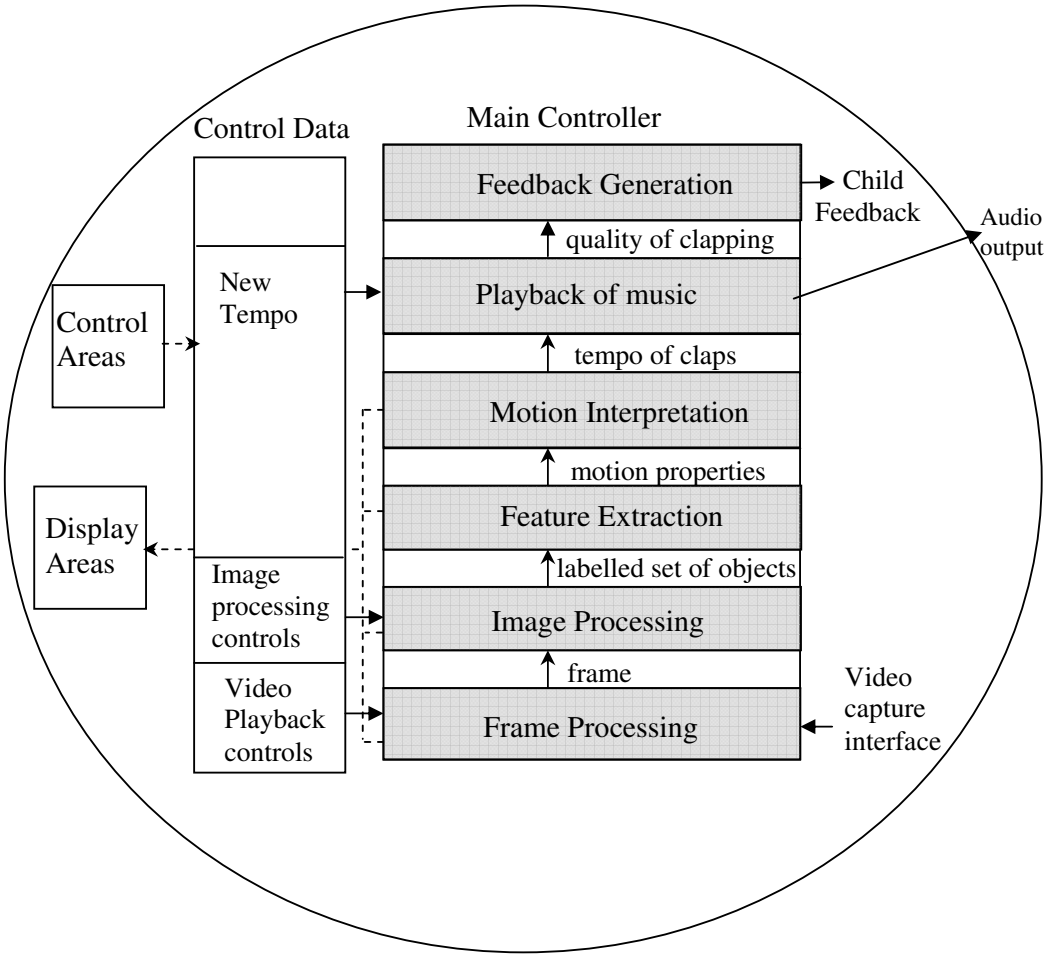



Figure 10: Second level decomposition of the system

Rather than further decomposition, we now give some further details on each of the components shown in figure 10 above.

### 4.3.4 Design of components

This section discusses each of the components shown in figure 10 on the previous page. The image processing component is by far the largest and therefore requires quite an extremely detailed and lengthy design description. The control and display areas component will not be discussed in this section since in was discussed in great length in the graphical user interface design (section 4.1).

#### 4.3.4.1 Control Data

The control data is all the options and values that the user can change through the user interface. These values influence various parts of the system.

**New Tempo**

This variable can be changed using a slider (show in figure 3) and the tempo of the music is update accordingly;

*audioTempo = newTempo*

*were audioTempo is the tempo of the currently playing audio track*

**Image Processing Controls**

Hue, saturation and brightness are sliders which are used to fine tune the segmentation process. The values of the sliders are stored as integers and are passed into the image processing component.

A variable needs to be used to indicate the status of each of the following operations, all of which can be on or off at any one time;

- Open
- Close
- Threshold (Average)
- Threshold (Background)

**Video Playback Controls**

These controls influence the playback of the video sequence, when running the program from a video file. Play and pause both use the same variable. Play sets step to false and pause sets step to true. When step is set to true the automatic frame processing is stopped and won't start again until the play button is pressed. When the program is in the state the forward and backward buttons are used to control the playing of the video sequence.

#### 4.3.4.2 Video capture interface

The video capture interface is responsible for accepting an input from either a video file or a web camera and producing a video sequence as an output. This video sequence will then be passed into the frame processing object.

#### 4.3.4.3 Frame Processing

The frame processing object takes a video sequence as an input and splits the video sequence up into frames. These individual frames are passed into the image processing object.

#### 4.3.4.4 Image processing

This component is the heart of the system. It is passed an individual frame of the video sequence as an input and outputs a labelled set of objects. Figure 11 below the shows the individual processes involved in this.

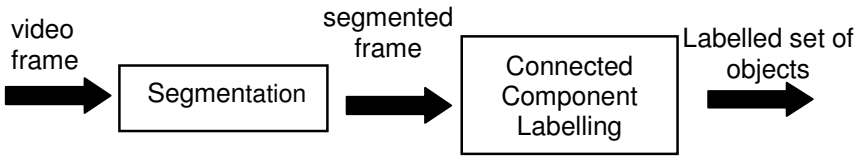
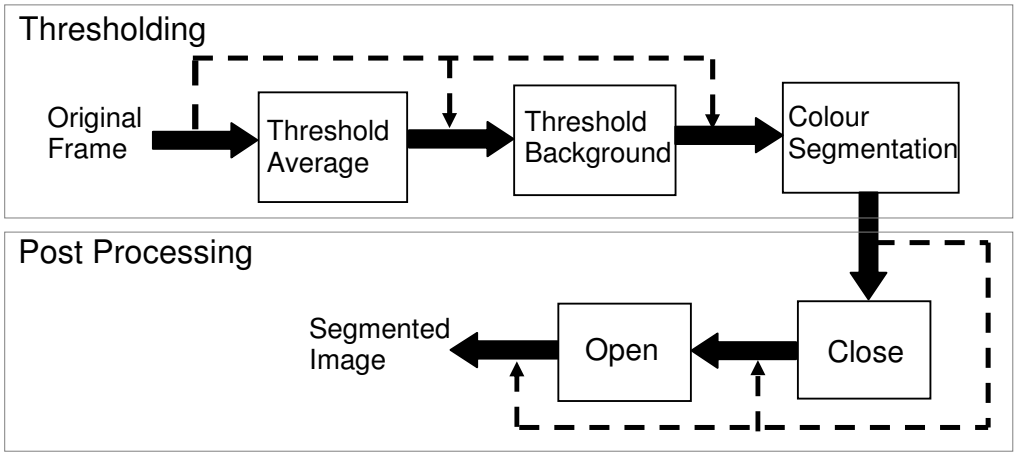



Figure 11: Decomposition of the image processing component

A more detailed description of each of above processes is outlined below.

### 1. Segmentation

Segmentation is the process of separating an image into regions of interest (hands) and a background. The segmentation process can be divided into two distinct stages, thresholding and post processing. Both of these processes can be further divided into smaller components. This is shown in figure 12 below.




Note: Process doesn't start until the user clicks a colour to track

Figure 12: Breakdown of the segmentation process

**a) Thresholding**

Thresholding is the process of converting a colour image into a black and white image. The regions of interest (hands) are turned white and everything is else is changed to black.

As can be seen from figure 10 there are three distinct stages in the thresholding process. The first two stages are optional and can be turned off or on by the user. These processes can improve the quality of the segmentation. The third process thresholds the image by colour. These processes are described in more detail below.

**Threshold Background**

ThresholdBackground compares every pixel in the current frame to a frame taken of the background by itself. If the pixel (of the current frame) is within a certain colour distance of the background pixel, it is set to black, otherwise it is left as it is. Threshold background essentially removes the background from every frame, leaving an image of the child against a black background.

The pseudo code of this function is outlined below;

```
for every pixel Pij in currentFrame
        if Pij lies within colour distance of backgroundPixel ij then
                set Pij to black
        else
                do nothing
```

**Threshold Average**

Threshold average takes an average grey level value for the current frame. It sets every pixel which is brighter than this value to a background pixel (i.e. black). This function works on the assumption that the background will generally be a brighter colour (white, cream etc.) than the objects which are to be tracked.

The pseudo code of this function is shown below;

```
avgback = average greylevel of the currentFrame
for every pixel Pij in currentFrame
    if Pij > avgback
        set Pij = black
    else
        do nothing
```

**b) Colour segmentation process**

The colour segmentation process separates the hands from the background by colour. The user selects the colour of the object which he or she wants to track by clicking on the input video sequence. When the user does this a Boolean value is set to true and the segmentation process will begin. The user can change the colour thresholds by using the hue, saturation and brightness sliders contained in the image processing window (shown in figure 3). By changing these values the user can fine tune the segmentation process. The hue, saturation and brightness (HSB) colour model was chosen instead of the standard red, green and blue (RGB) colour model because extensive testing of both colour models (using the prototype) proved that the HSB colour model produced better results. This is because, the colour of the gloves should have the same hue value throughout, however it could have different saturation and brightness values because of the variations in lighting conditions.

The pseudo code of this function is shown below;

```
for every pixel Pij in currentFrame
    if Pij lies within valid range of the hue, saturation and brightness
    slider values
        set Pij to white
    else
        set Pij to black
```

## 1. Post-processing

Post-processing is used to clean up binary images. It fills in holes and removes isolated noise pixels. There are two processes involved in this; open and close. Open and close are both formed using two mathematical morphology operations; erosion and dilation. Erosion removes isolated noise pixels and smoothes object boundaries. However it also removes the outer layer of object pixels i.e. the object becomes slightly smaller. Dilation fills in holes and smoothes object boundaries. However it adds an extra outer ring of pixels onto the object boundary i.e. the object becomes slightly larger. The problem with erosion and dilation is that they change the size of the objects. To overcome this we can combine erosion and dilation to form two new operations known as open and close.

### a) Open

Opening is used to remove `salt noise' in image (i.e. white noise pixels amongst a black background). An open is an erosion followed by a dilation. The amount of white pixels which are removed depends upon the size of mask which is used for the open operation.

### b) Close

Closing is used to remove `pepper noise' in images (i.e. black noise pixels amongst a white background). A close is an dilation followed by a erosion. The amount of black pixels which are removed depends upon the size of mask which is used for the close operation.

The order of the two morphology operations is very important and affects the outcome of the post processing stage. It has been decided to perform a close first, followed by an open. By performing the operations in this order, the black speckle in the objects (hands) is removed first. If the operations were carried out in the opposite

order, the black speckle could be joined together, splitting up the objects. Therefore performing a close first reduces the chances of this happening.

**Connected Component Labelling**

Connected component labelling scans an image and groups its pixels into components based on pixel connectivity. Each group is then assigned a unique colour value according to the component that it was assigned to. The pseudo code for this operation is shown below

*Initialise each pixel to a unique value*
*Loop three times*

> *From top hand left corner, to bottom right hand corner propagating the local maximum*
> *From bottom right hand corner to top left hand corner propagating the local maximum*

*end*

Connected component labelled is a standard image processing operation and so will be not discussed in any length of detail at this time.

The labelled objects are then ranked by size. The area of the two biggest objects is found by simply counting the pixels for each object.

The area of the two biggest objects is compared and if the area of object one is significantly bigger than the area of object two then the hands are determined to be touching. In this case all objects except the largest one are discarded. If the hands are not determined to be touching, the two biggest objects are kept and the rest of them are discarded. So this object will return either one or two objects.

#### 4.3.2.5 Feature-extraction

Now the hands have been separated from the background, the motion properties can be extracted. There are three motion properties to be extracted for each hand; the centre co-ordinates in the horizontal (x) direction, the speed and the direction. Each one of these properties will now be discussed in more detail.

**The centre co-ordinates in the horizontal (x) direction**

A decision has been taken to ignore the vertical position of the hands. This is because by using co-ordinates in the horizontal direction and the area, we have enough useful information to interpret the current frame (this is discussed in more detail in the next section)

Since each hand will be labelled with a different colour, we can substitute the variable colourOfObject with the colour of the object we want to calculate the area for.

Pseudo code for finding the co-ordinates in the x direction:

*Total = sum of all x co-ordinates of all pixels of object*
*Centre = total/sum*

```
for every pixel Pij in currentFrame
{
        if Pij = colourOfObject
                total = total + i
        else
                do nothing
}
x = total/area
```

**Speed**

The speed is simply worked out by taking the distance moved over the last two frames and dividing this result by two;

*Speed = (currentCentre – prevCentre)/2*

**Direction**

The direction is worked out by examining the current centre co-ordinate and the previous centre co-ordinate;

*If (currentCentre and previousCentre lie within a certain distance)*
*Direction = still*
*Else If (currentCentre < previousCentre)*
*Direction = right*
*Else if (currentCentre > previousCentre)*
*Direction = left*

*Where direction will be replaced by greenHandDirection and yellowHandDiretion.*

Note: The hands do not have to be exactly still in order to be classified as such, instead a small leeway is given. This decision was taken to allow for the variations in working out the centre co-ordinate from frame to frame.

These features will be displayed in the information area. They will also be passed into the motion interpretation object which will interpret the current motion.

#### 4.3.2.6 Motion Interpretation

Using the features which have been extracted from the frame, the current motion can be classified into one of the following five scenarios;

- Hands moving apart
- Hands moving together
- Hands still
- Hands touching
- Other (for any scenarios which doesn't fit into one of the above categories)

The pseudo code for each of these processed is outlined below;

**Hands moving together**

*if (GreenHandDirection == right) and (YellowHandDirection == left)*
*Hands are moving together*

**Hand moving apart**

*if (GreenHandDirection == left ) and (YellowHandDirection == right)*
*Hands are moving apart*

**Hands still**

*if (GreentHandDirection == still ) and (YellowHandDirection == stillt)*
*Hands are still*

**Hand touching**

This scenario was already worked out in the componentLabelling object. However some further interpretation has to be done, since hands touching and hands clapping are not the same. The hands are only said to be clapping during the first frame of when the hands are touching. When this occurs a timer is started and the time between claps is worked out.

#### 4.3.4.7 Payback of music

As discussed before (section 4.3.3) The tempo of the audio sequence can be controlled by the user, using the audio tempo slider.

At anyone time the tempo of the currently playing song is given by the variable audioTempo.

#### 4.3.2.9 Feedback generation

Feedback is generated for the child by comparing the timing of the claps to the timing of the music. The quality of the clapping is classified into one of five categories. The categories are outlined below along with the margin of error that is allowed;

- veryGood: 10% margin of error
- good: 20% margin of error
- ok: 40% margin of error
- bad: 60 % margin of error
- veryBad: 80% margin of error

It was decided to produce feedback to the child using absolute values i.e. the feedback will be updated every frame depending on how closely the child is clapping in time with the music. Another approach would be to use an expert system, which would

smile if the child began to improve but was still clapping badly out of time with the music. The reason the first approach was chosen over the second was because it was felt that the second approach could be confusing to the child e.g. if the child was clapping out of time with the music and a smiley face was displayed, the child might thing that he or she is doing well and so wouldn't try to improve.

#### 4.3.2.10 Child Feedback

The feedback discussed in the last section is presented to the child in the form of a face (this was discussed in section 4.1.2)

# 5. IMPLEMENTATION

This section details how the specification and design have been implemented. It is mainly concerned with the areas were there are significant gaps between the design and the implementation of the system.

## 5.1 Technology Used

Java was chosen as the implementation language for the following reasons;

- Java is an extremely portable language and can run on any system which has the java virtual machine installed
- Java has a wealth of useful libraries e.g. libraries to assist with the processing of images, sounds and videos.

A standard, low budget web camera was used for this system. In order to get the optimum performance from the web camera it was found that automatic white balance should be turned off. Tests showed that the quality of the colour segmentation considerably deteriorates when automatic white balance is enabled. This happens because the colour that we are trying to track can change shade or even colour during the course of the video making in practically impossible to track.

## 5.2 Implementation of Components

This section discusses the key algorithms and the implementation decisions for each component.

### 5.2.1 Creation of display and control areas

The user interface was implemented exactly as previously described in the graphical user interface design (section 4.1). It was implemented in java swing, using standard java practices and as a result a detailed description of the implementation is not needed. The creation of all display and control areas is contained in the Main class. The main class is responsible for the creation of the user interface, as well as for connecting all the other classes together.

One area of note is the creation of internal windows. There are five internal windows and a desktop (parent) pane in the system. Java however, doesn't support the making of the desktop pane scrollable. This means when an internal window is moved outside the desktop pane's viewable area, scrollbars will not appear. This makes it possible to lose children frames. In order to include scrollable functionality in the system a class MDIDesktopPane was used. MDIDesktop pane is an extension of JDesktopPane which adds the functionally of adding scroll bars when windows move too far to the left or bottom. It is based on the code provided by javaworld.com (see the references section for a link to an article about this issue and a download link to the source code).

Action Handler is a private, nested class (inside the class) which is responsible for the handling of events i.e. when a user clicks on a button or a menu item. Since it follows exactly from the design section and there are no major implementation issues, this class will not be discussed.

### 5.2.2 Control Data

This component is made up entirely of variables and data structures which are included in numerous different classes. Because of this, this component will not be discussed in the implementation section. Any important variables and data structures will be instead be discussed in the component which they are contained in.

### 5.2.3 Video Capture Interface

All of the Video processing tasks were implemented using Java Media Framework (JMF). JMF is a library which enables video and audio to be added to java applications. It is an optional package which extends the functionality of the Java platform. This is quite a detailed and complex area and as a result we need to introduce some new terminology;

**Player**: Takes as an input, a stream of video data and returns in to the screen.

**Processor:** A processor extends a player. It has more control over what processing is performed on the input stream than a standard player.

**Data source**: The location of the media which is to be presented by the player. A data source can be created from either a media locator or a URL.

**Media Locater**: Describes the media that a player displays.

**Manager**: Used to create players from a URL, a MediaLocator or a DataSource.

The first video processing task is to capture a video sequence. This can be from either from a web camera or from a video file. A processor will be used to play the video sequence rather than a player. This is because a processor allows individual frames to be extracted from the video sequence.

If the input is from web camera, a list of devices connected to the computer has to be found. A media locator is created using one of the devices. A processor can then be created from the media locator. The pseudo code for this process is outlined below.

```
// create a vector of all the video devices connected to the computer
Vector devices = CaptureDeviceManager.getDeviceList()

// create an object of the first video device
CaptureDeviceInfo cdi = devices.elementAt(0)

// create a media locater object
MediaLocator  ml = cdi.getLocator()

// create a processor from this media locater object
processor = Manager.createProcessor(ml)
```

The video sequence can also be from a video file. This involves using a manager object to create a processor from a URL. This pseudo code for this operation is shown below;

```
URL url= new URL(videoFile)
processor = Manager.createProcessor(url)
```

Before a processor can actually begin to play a video sequence, it has to pass through eight stages. These stages are shown in figure 12 on the following page.

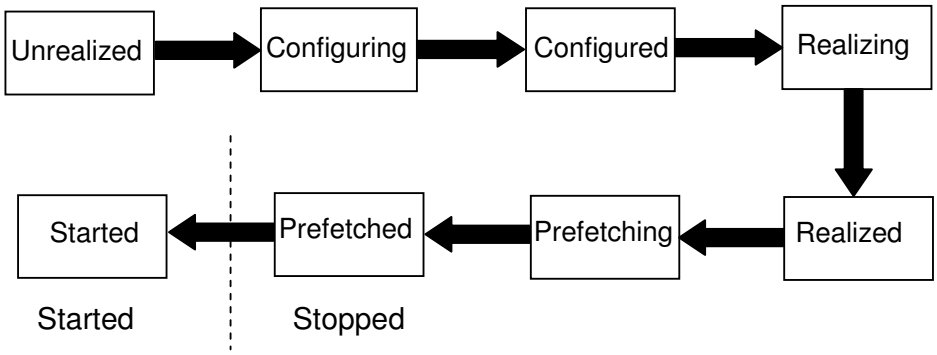



Figure 14: Diagram showing the different stages of a processor

In order to prevent the processor object from progressing to the next state too early, a wait for state method has been created. This method checks that the processor has successful reached the current state (by a call to processor.getState() ). If it has, it is allowed to progress to the next state, where as if it hasn't it is blocked until it does so (using the thread's wait method). This method is extremely important because if a processor progresses to any of the states too early, a malformed processor will be created. The pseudo code for this method is shown below.

```
boolean waitForState(int state)
    synchronized (waitSync)
        while (processor.getState() != state && stateTransitionOK)
        waitSync.wait()
    return stateTransitionOK
```

### 5.2.4 Frame processing

In order to access individual frames of the video sequence, a codec has to been added to the video sequence. This is done by firstly getting the TrackControls from the processor and then setting the codec on the video track:

```
Codec codec[] = {
                    new PreAccesCodec()
                    new PostAccessCodec()
                }
            videoTrack.setCodecChain(codec)
```

This means that the codec's process methld will be the ‘callback’ whenever a video frame goes through the plug-in. So for every frame in the video sequence, the process method of the postAccessCodec will be called, with the current frame as a parameter. postAccessCodec is a class nested inside the main class. It is based on the example code provided by Sun Microsystems (see the reference section for a link to this code). postAccess extends PreAccessCodec.

One of the requirements of the system was to single step through a video sequence for analysis purposes (requirement 2.4.4(4)). In order to do this the automatic frame processing which is carried out by the postAccessCodec has to be stopped. This is done by using a Boolean variable called step. The automatic frame processing operations are then turned off. This happens when the user presses the pause button (on the video control panel, below the input video sequence). The system is then halted until either the forward frame, backward frame or play button is pressed. If the play button is pressed the video sequence starts to play again, the Boolean variable step is step to false and the segmentation process resumes. If either of the backward frame or forward frame buttons are pressed, the current frame is replaced by the next frame or the previous frame respectively and a method update is called. Update is a

method which updates the segmentation video, with the new segmented frame. (it also updates all the user interface areas, with the correct motion property values).

No frame processing starts until a variable called detectColour is set to true. This is set to true when the operator selects the colour of the object to be tracked (by clicking on the object on the input video sequence). This process will be discussed in more detail in the image processing operation

When the $5^{th}$ frame is the current video sequence is passed through the accessFrame method, a method grabFrame is called. This method passes the current frame into the processImage object (by calling processImage.setBackground(image)). This image is used if threshold background is turned on (this process will be explained in more detail in the image processing section).

### 5.2.5 Image Processing

The processImage and componentLabelling classes make up the image processing component which was described in the design section. The processImage class is concerned with the segmentation of the image and the componentLabelling class labels the image. Both of these classes will now be described in more detail.

#### 5.2.5.1 ProcessImage

The first implementation issue is to do with the detectColour variable which was mentioned in the frame processing section. This variable is set to true, when the colour of the object to track has been selected. When the user clicks on the input videoSequence, a method ( setColourPixel(int x, int y) ) is called in the processImage object (from the main class) with a parameter of the co-ordinates which the user clicked on. This pseudo code for this operation is shown on the following page

```
public void setColourPixel(int x, int y)
{
        find the average red component of the 9 * 9 neighbourhood around the
                selected pixel
        find the average green component of the 9 * 9 neighbourhood around
                the selected pixel
        find the average blue component of the 9 * 9 neighbourhood around
                the selected pixel
}
```

An average colour of the 9*9 neighbourhood surrounding the current pixel is used instead of the actual colour value for the pixel clicked to give a more accurate result. The red, green and blue components of the pixel are they stored as integer values, and are used by the various image processing operations which are described later in this section. The red, green and blue components are calculated by method calls to the colour class. The colour class is a utility class which was written to perform some colour calculations e.g. extracting the red, green and blue colour components from a pixel and converting red, green and blue value to hue saturation and brightness values.

Every pixel in this image is then looped through and the appropriate imaging operations are called. The pseudo code for this process is given on the next page.

```
 for every pixel Pij in currentFrame
red = colour.getRed(bufferedImage.getRGB(x,y));
green = colour.getGreen(bufferedImage.getRGB(x,y));
blue = colour.getBlue(bufferedImage.getRGB(x,y));
    if (thresholdAverageOption == true && colourChoosen == true)
        thresholdAverage(average, red, blue, green, x, y)
     else if (thresholdBackgroundOption == true && colourChoosen == true)
        thresholdBackground(red, blue, green, x, y)
    else if (colourChoosen == true)
        colourSegmentation(red, blue, green, x, y)
```

This differs slightly from the design, in that there is only one loop, with each thresholding option called for every pixel in the loop. In the design section three loops were used, one for each of the thresholding options. One loop is used instead of three for efficiency purposes.

The red, blue and green components of the current pixel are passed into each of the methods mentioned above. Since each of these methods where described in extensive detail in the design section, another detailed description will not be given. One point to note though, is that the red, green and blue pixel values which are passed into the colourSegmentation method are converted to hue, saturation and brightness values. This is so that they correspond to the hue, saturation and brightness sliders in the image processing panel. The conversation of these values takes place in the colour class and is a standard imaging operation.

The post processing operations, open and close are then applied to the frame (if they are turned on, using the open and close buttons in the image processing control panel)

As mentioned in the design section the effectiveness of both post-processing operations depends on the size of the mask which is used. Extensive testing was carried out to find the optimum value for these masks. The larger the mask, the more noise pixels are removed (however some valid pixels might be removed as well). For the close operation it was found that a mask of between a 2*2 and a 3*3 proved the most effective. A mask in between these values was created by using a 3*3 mask and setting some of the bits to 0 so that they have no effect. The mask that was used for the close operations is shown below;

010
111
010

A mask of 4*4 was used for the open operation.

The segmented frame is then returned to the main class, which calls the componentLabelling object with a parameter of the segemented frame.

#### 5.2.5.2 ComponentLabelling

The first task of the componentLabelling class is to label the image. The component labelling algorithm is based on the code snippet supplied by Prof. Danny Crookes (see appendix 5 for the original code). Because of this, and because the basic pseudo code for this algorithm was described in the design section, no further explanation of this algorithm will be given.

The area of each the two largest labelled objects is then found. This is done by creating a histogram of the image i.e. the colour of each pixel is plotted against the number of pixels that are this colour. This histogram is created as a 1D array. This one 1D array is looped through and the largest two objects are found

The area of the two largest objects is then found. If the area of one hand is twice the area of the other hand, the objects are said to be touching.

The objects are now labelled and must be correctly colour coded. It is extremely important that the objects are coloured coded the same colour from frame to frame. An example will be used to illustrate why this is so important. For the current frame, the object on the left is labelled yellow, and the object on the right is labelled green. Now on the next frame, the object on the left is labelled green and the object on the right is labelled yellow. Even though the objects haven't moved, the system will think that the objects have swapped places and therefore the distance, direction and speed motion properties will be worked out incorrectly. Therefore an algorithm has to been made to predict the position of the objects.

The algorithm starts off by labelling the object on the left yellow and the object on the right green. For every frame after this, the objects in the current frame are compared with the position of the objects in the previous frame. They are coloured the same colour as the closest object.

Now that a ranked list of objects has been extracted from the current frame, some features can be extracted from each of these objects. This brings us onto the feature extraction component.

### 5.2.6 Feature Extraction

Three motion properties need to be extracted from the current frame;

- Centre co-ordinates in the horizontal (x) direction
- Direction of motion
- Speed

Each of these will now be discussed in more detail

### 5.2.6 Centre co-ordinates in the horizontal (x) direction

The first motion property has in fact already been worked out, in the component labelling class. After this value has been calculated a passed into a hand object;

*greenHand.setCentreX(greenX)*

*yellowHand.setCentreX(yellowX)*

The hand class is responsible for holding data about each of the hands. Two instances of the hand class are created, one for the green hand and one for the yellow hand.

As mentioned in the previous before, the centre co-ordinates (in the x direction) are inputted to this class from the componentLabelling class. These values are stored in a 1D array using a circular bounded buffer approach. This is shown in figure 15 below

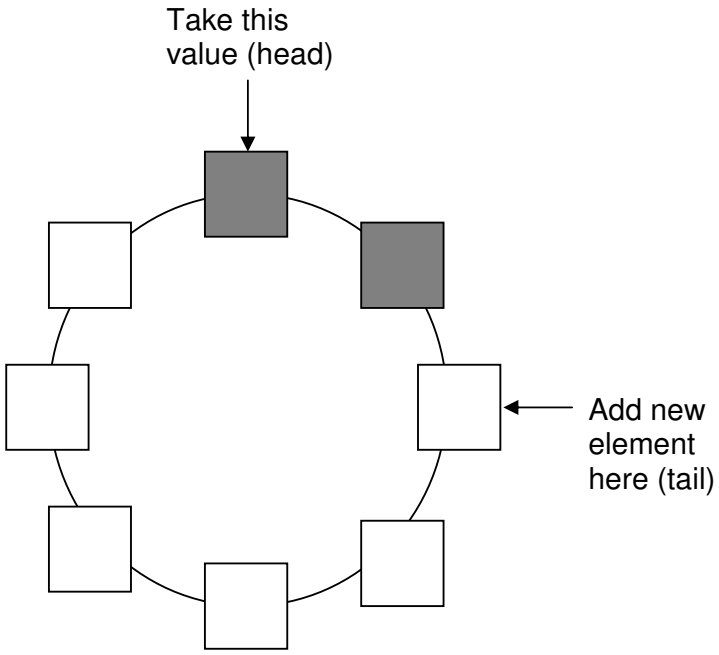



Figure 15: Diagram showing how the centre co-ordinates are stored in an array

It was decided to store the values in this way for a number of different reasons. Firstly so that the distance the hands have moved can be worked out over any number of frames (up to the size of the buffer). This proved very useful for experimental purposes and was helpful when finding the optimum number of frames to take the distance over (it was decided to take the distance over the last two frames). It also means that the system can be easily updated at a later stage e.g. the system can easily changed to find the distance/speed that the hands had moved over n number of frames.

When a call is made to setCentreX(int x) the integer value of x is added to the tail of the buffer;

*bufferX[tailX] = x*

*tailX = (tailX+1)%size*

A element can be taken from the buffer by calling getCentreX(). This method always returns the element at the head of the buffer. This method is implanted in such a way that successive calls to this method will keep returning the latest value added, until a new value is added to the buffer. This ensures that the right value is always returned.

#### 5.2.6.2 Speed

The speed for each hand is worked out between the previous frame and the current frame. It is also worked out in the hand class. It is worked out by taking the distance moved over the last couple of frames and dividing this distance by two.

#### 5.2.6.3 Direction

The direction is also worked out in the hand class. A detailed algorithm for this was given in the design section (see section 2.3.2.6) and therefore there is no need to going into any further detail.

Now that these motion properties have been worked out they can been displayed in the information area. The updateTextFields method extracts the motion properties (distance, direction) from the current frame by calling appropriate methods in the hand class.

Using these motion properties the current motion can be interpreted. This brings us onto the next section.

### 5.3.7 Motion interpretation

Most of the motion interpretation is carried out by the motion interpretation class. The class is called by the main class and the Boolean values which are returned from the method calls determine what icons are displayed in the information area. The algorithms determining the motion interpretation was discussed in the design section and so don't need to be mentioned again.

The component Labelling class is responsible for working out if the hands are touching. Using this information, it can be worked out when the hands actually clap. The hands are only 'clapping' the first frame of when they are touching. So a Boolean variable is set to false, after the hands touch for the first time and remains false until the hands start to move apart again. This ensures that the hands are only classified as clapping once during one 'clap'.

Every time that a clap occurs, the current time is recorded, this time is subtracted from the previous time to give the time between claps. This value is compared with the time between beats variable and then the according child feedback is displayed.

### 5.3.8 Playback of Music

Midi files are used as the audio sequence, as opposed to wav files or mp3s. This decision was taken for a number of reasons;

- A large number of midi files are freely available
- Information about a midi file (e.g. current tempo) is easily obtainable
- Midi files can be easily created and so if the operator wishes they can compose their own audio tracks

In order to play a midi sequence, a sequencer has to be created and a midi file is played through the sequencer.

```
sequencer = MidiSystem.getSequencer()
sequencer.open()
sequencer.setSequence(MidiSystem.getSequence(midiFile))
sequencer.start()
```

The tempo of the music is then recorded and using this the time between beats is worked out. The time between beats is compared with the time between the claps and is used to produce the child feedback.

```
timeBetweenBeats = 60/(sequencer.getTempoInBPM())
```

### 5.3.9 Feedback Generation

Feedback generation is calculated by comparing the timeBetweenBeats variable (which was calculated in the last section) and the time between claps.

### 5.3.10 Child Feedback

The feedback discussed in the last section is presented to the child in the form of a face (this was discussed in detail in section 4.1.2)

### 5.3.11 Utility Classes

These are classes which do not directly correspond to any of the components mentioned in the design but perform mandatory functions.

**MovieFilter**

MovieFilter is a small utility class which extends FileFilter. It is responsible for making sure that the video file that the user tries to open is of type avi or mpeg.

**Colour**

Colour is a utility class which contains various coloured related methods which are not part of the java imaging library. They were grouped together in one class for code reusability purposes.

# 6. Testing

There were two types of testing carried out on the system. White box testing and black box testing, these are outlined in more detail in the sections below.

## 6.1 White box testing

White box testing was carried out during the development of the system using test harnesses. These test harnesses were used to test individual classes before there were integrated with the main system. A good example of this is the hand class. Before it was integrated, tests were carried out to make sure that correct value was being pulled out of the array. Some of these tests are shown below;

```
hand1.setCentreX(10);
hand1.setCentreX(10);
hand1.setCentreX(1);
hand1.setCentreX(2);

System.out.println(hand1.getCentreX());
System.out.println(hand1.getCentreX());
System.out.println(hand1.getCentreX());
System.out.println(hand1.getCentreX());
```

White box testing proved invaluable for this system, as prevented major problems when adding new classes to the system.

## 6.2 Black box testing

Black box testing involved using the system and making sure it operated correctly. Black box testing was carried out during the development of the system, to make sure that the core functions didn't break when new elements were added to the system.

Exhaustive black box testing was also carried out when the development of the system was finished. These tests were carried by volunteers who had no knowledge of the internal workings of the system. As well as testing the functionality of the system these tests provided feedback on how to make the user interface more friendly.

Some examples black box tests are shown in the below table 2 below.

| Test Case | Description of test case | Expected behaviour | Result |
|---|---|---|---|
| Change input to input from a web camera when no web camera is connected | Make sure a web camera is not connected to the computer. From the input menu select web camera. | A error message should be displayed. | Pass |
| Click on an object to track | Click on an area of the input video sequence | The segmentation process should be started | Pass |
| Change the audio tempo | Using the audio slider, change the tempo of the audio sequence | The tempo of the audio sequence should changed to the new tempo selected by the user | Pass |
| Change the audio track | From the audio menu, select a new audio sequence to play | The currently playing audio sequence should stop playing and the selected audio sequence should begin to play. | Pass |

Table 2: Examples of the type of test cases which were performed on the system

## 6.2 Test conclusions

The extensive testing which was carried has made the system extremely robust and reliable.

# 7. Conclusion

## 7.1 Evaluation

The system is well designed, robust and fulfils all the requirements (including the optional ones) which were set out in section two. The user interface is easy to use and all of the test subjects were able to use the system with little or no prompting. Unfortunately due to time constraints, the system tested on children therefore no comments can be made on how effective the child feedback was.

## 7.2 Findings

A number of findings have come out of the system. The first major finding is to do with the segmentation process. A number of optional operations are built into the system to improve the quality of the segmentation (e.g. threshold background). It was found however, that in the majority of cases these options do not need to be used. They only need to be used in difficult lighting conditions.

The system runs in real time, when none of the segmentation options are turned on. However when either, or both of the post processing operations (open and close) are turned on the system slows down quite significantly. Therefore there is little or no point using these operations when running the program live from a web camera.

The threshold average didn't perform as well as expected. This function works on the principle that the background will be a brighter colour than the objects which are to be tracked. However there are problems with using a light colour as a background. which can cause reflections. These reflections, when captured by a web camera can turn into a multitude of colours (usually yellow, but sometimes blue or red). If the gloves are the same colour as these reflections, the program might classify the reflections as hand objects. Therefore it is better to use a darker colour as a background and by doing this threshold average will not work.

Out of all the optional processes to improve the segmentation process, threshold background was found to be the most valuable. It successfully enhances the quality of the segmentation, especially when the background is of a similar colour to the colour which is being tracked.

## 7.2 Future Enhancements

Due to the research nature of this project, there are a large number of enhancements which could be made to this system. A few of these have been outlined below.

The equipment used was very low budget. If more expensive, high quality web camera was used the results of tracking the hands could be improved. At the moment if the child were to move his hand very fast across the screen, they would just appear as flashes and the system would not be able to correctly interpret what is happening.

The interpretation of motion could be improved on. At the moment it is decided if the child is clapping by examining the area of the hands and the previous x co-ordinates. While this is a good way to classify the motion, the system can be fooled if the child moves one hand behind another. One way of potentially stopping this from happening is to examine the angle of the hands. Just before the child claps both hands should be vertically straight. If however the hands miss and one hand passes behind the other, you would expect both hands to be slightly angled towards the ground. Another way to determine if the child claps or the hands simply cross path is to use two web cameras so that a 3D image can be built up. One web camera would look down on the child and the other would be face on.

The system could create a log of how well a child is clapping in time with the audio sequence. Over a period of time this log could be reviewed and improvements could be easily spotted.

## 7.3 Summary

In summary this project has been a success. A system has been created which can accurately track and interpret a child's movements using low budget hardware. The project was not meant to address and solve all the issues in this area, but rather to open people's eyes to the possibility that computer systems can be used to aid child development.

# References

**Image processing resources**


Image Processing Learning resources:
http://homepages.inf.ed.ac.uk/rbf/HIPR2/hipr_top.htm

Programming in Java Advanced Imaging (Sun Microsystems):
http://java.sun.com/products/java-media/jai/forDevelopers/jai1_0_1guide-unc/JAITOC.fm.html

Learning java 2D (Sun Microsystems):
http://java.sun.com/developer/technicalArticles/GUI/java2d/java2dpart2.html

Wayne, N., 1986. *An Introduction to Digital Image Processing*, UK: Prentice/Hall International.

Efford, N., 2000. Digital Image Processing: a practical introduction using Java, England: Addison-Wesley.


**Java Media Framework Resources**


JMF API Specification and JMF API guide:
http://java.sun.com/products/java-media/jmf/2.1.1/specdownload.html

JMF Programmers guide:
http://java.sun.com/products/java-media/jmf/1.0/guide/index.html

JMF forum:
http://forum.java.sun.com/forum.jspa?forumID=28

Frame Access Demo code
http://java.sun.com/products/java-media/jmf/2.1.1/solutions/FrameAccess.html

Article about Conquering Swing deficiencies in MDI development:

http://www.javaworld.com/jw-05-2001/mdi/jw-0525-mdi.zip

Source code for MDIDesktop

http://www.javaworld.com/jw-05-2001/mdi/jw-0525-mdi.zip

**Java Sound Resources**

Java Sound API:

http://java.sun.com/products/java-media/sound/

Java Sound Resources:

http://www.jsresources.org/

# APPENDICES

The appendices contain information that is not appropriate to be included within the main body of the dissertation but is required for assessment. Below is a list of each of the appendices.

### Appendix 1

Project Problem Description

### Appendix 2

The source code for the project is quite extensive and as a result it is not going to be included in the appendix. Instead it is included on the attached cd – see appendix 5.

### Appendix 3

An installation guide and user manual

### Appendix 4

Examples of inputs and the corresponding output from the system

### Appendix 5

The component labelling source code supplied by Prof. Danny Crookes.

### Appendix 6

Contained on the source disk is the complete program source code

### Appendix 7

The signed project minute forms